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Forest Health Protection

Pacific Southwest Region

Northeastern California Shared Service Area

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To: District Ranger, Mt. Hough Ranger District, Plumas National Forest

Subject: Evaluation of stand conditions in proposed commercial and pre-commercial thinning units and California Spotted Owl habitat maintenance units with respect to forest insects and diseases in the Moonlight Restoration Project (FHP Report NE17-01)

At the request of Beth Waterston, Forester, VMS Enterprise Unit, Danny Cluck, Forest Health Protection (FHP) Entomologist and Bill Woodruff, FHP Plant Pathologist visited the Moonlight Restoration Project on November 8, 2016. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss proposed alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance agents such as fire, insects and diseases.

Key findings:

- Overstocking is increasing the susceptibility of forested areas to high levels of bark beetle-caused tree mortality during periods of drought.
- Lone Rock and Boulder Campgrounds and the Antelope Lake Day Use Area are extremely overstocked.
- 2016 aerial detection surveys, which provide a project-wide assessment of current conditions, recorded elevated levels of tree mortality in a few of the proposed treatment units.
- Forest pathogens, especially true fir dwarf mistletoe and Heterobasidion root disease, are well established in some stands and contributing to increased white and red fir mortality.
- The proposed commercial and pre-commercial thinning treatments that are outside of wildlife habitat units should effectively reduce stocking to levels that lower the susceptibility to bark beetle-caused tree mortality.
- Hand thinning up to 6” DBH in units related to California Spotted Owl habitat maintenance is not likely to reduce stand density to levels that decrease susceptibility to bark beetle-caused tree mortality.
- All silvicultural thinning prescriptions need to account for potential elevated levels of white fir mortality due to overstocking, drought, poor growing sites, root disease and/or dwarf mistletoe infections.

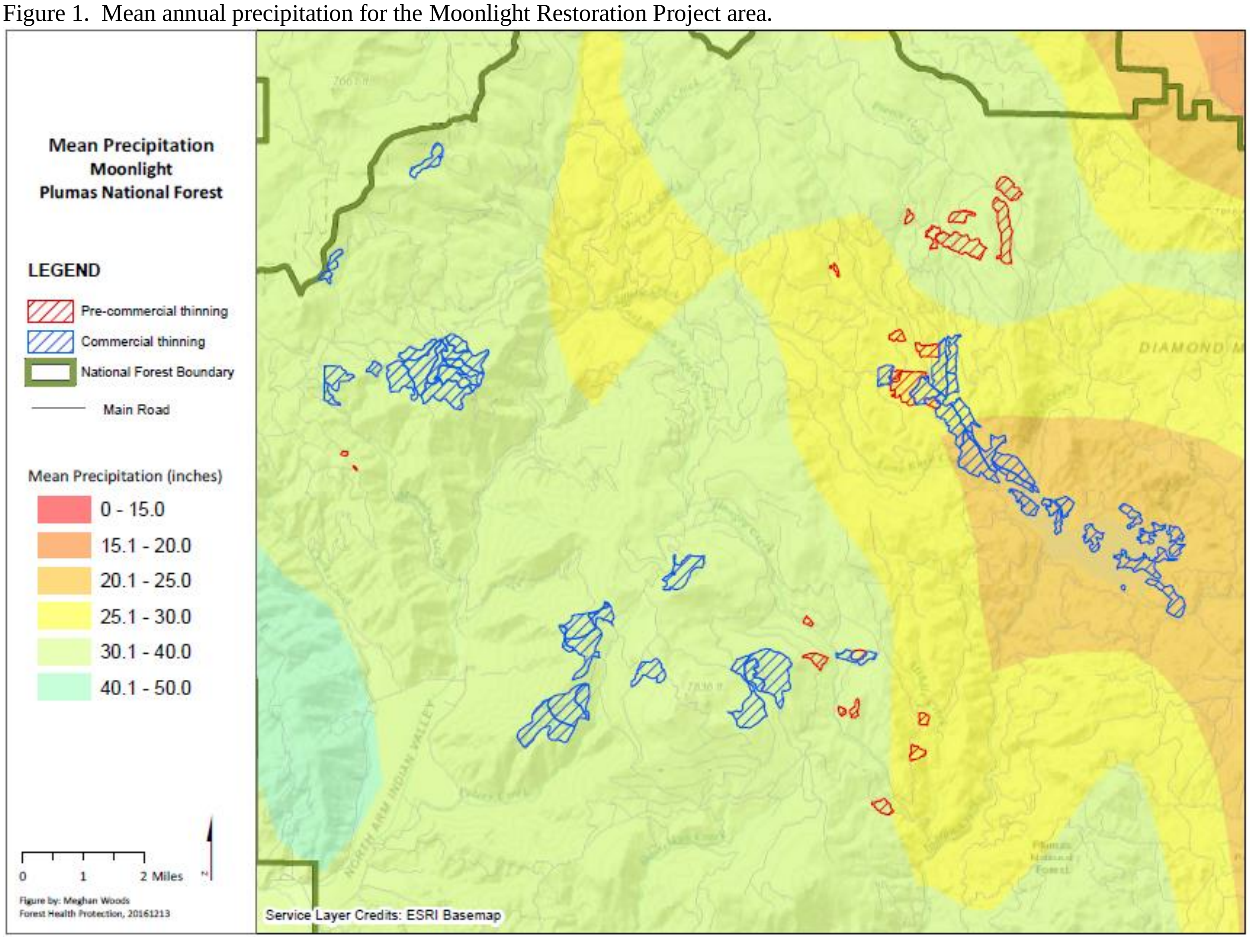
Danny Cluck
Forest Entomologist
530-252-6431
dcluck@fs.fed.us

Bill Woodruff
Plant Pathologist
530-252-6880
wwoodruff@fs.fed.us

Description of the project area

The Moonlight Restoration Project is located approximately 12 miles southwest of Janesville, CA (40.191992 and 120.697397) with treatment units dispersed over a very large area. The elevation of the project area ranges from 4,600 to 7,300 feet with average annual precipitation ranging from 20 – 40 inches. About two thirds of the proposed commercial and pre-commercial treatment units receive greater than 30" of average annual precipitation (Figure 1). Units located within lower precipitations zones consist primarily of ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*) and white fir (*Abies concolor*). Units located within higher precipitation zones are primarily Sierra Nevada mixed conifer stands with ponderosa pine, Jeffrey pine, Douglas-fir (*Psuedotsuga menziesii*), sugar pine (*Pinus lambertiana*), incense cedar (*Calocedrus decurrens*), and white fir. California Spotted Owl habitat maintenance units (not mapped) are mostly mixed conifer within the 30" to 40" precipitation zone. The pre-commercial units are pine plantations (ponderosa and/or Jeffrey) with scattered ingrowth of white fir and sugar pine.

Figure 1. Mean annual precipitation for the Moonlight Restoration Project area.



Management objectives

There are multiple management objectives for the Moonlight Restoration project but <u>this evaluation will only address the proposed commercial and pre-commercial thinning units and the California Spotted Owl habitat maintenance units</u>. Various levels/types of thinning are proposed for these units to reduce stand density. This includes the removal of sawlogs and biomass to achieve stocking objectives. Thinning in wildlife habitat units will be limited to the removal of

trees <6” dbh with the objective of reducing ladder fuels around larger conifers. Density and fuels reduction would generally occur with a variable thinning strategy. Variable thinning would reduce stand density and change species composition to a more sustainable condition by removing trees from all size classes (< 30” dbh) outside of designated wildlife habitat areas, creating gaps and clumps, and removing competition from around old growth trees. This type of treatment would begin to move these stands to a more resilient condition that is consistent with Regional ecosystem restoration goals.

Forest insect and disease conditions

**Note: Not all units were inspected during this evaluation. Specific units discussed in this evaluation are representative and comparable to other units within the Moonlight Restoration Project. Several Moonlight Restoration units located within lower precipitation zones near Antelope Lake (Units #440, 455, 454, 436 -438) were evaluated in 2014 (FHP Report NE14-04) for the then proposed Lone Rock Forest Health project and are representative of other pine dominated units in this area.*

Tree mortality attributable to forest insects and/or diseases is occurring at relatively low levels (slightly above background mortality levels) in most of the units covered during this evaluation. Areas with slightly higher levels of tree mortality were mapped by the 2016 Aerial Detection Survey (Figure 4).

White fir mortality caused by the fir engraver beetle (*Scolytus ventralis*) was observed in most mixed conifer locations. This mortality was often associated with Heterobasidion root disease, caused by *Heterobasidion occidentale*, or true fir dwarf mistletoe infections (*Arceuthobium abietinum*) (Figure 2).

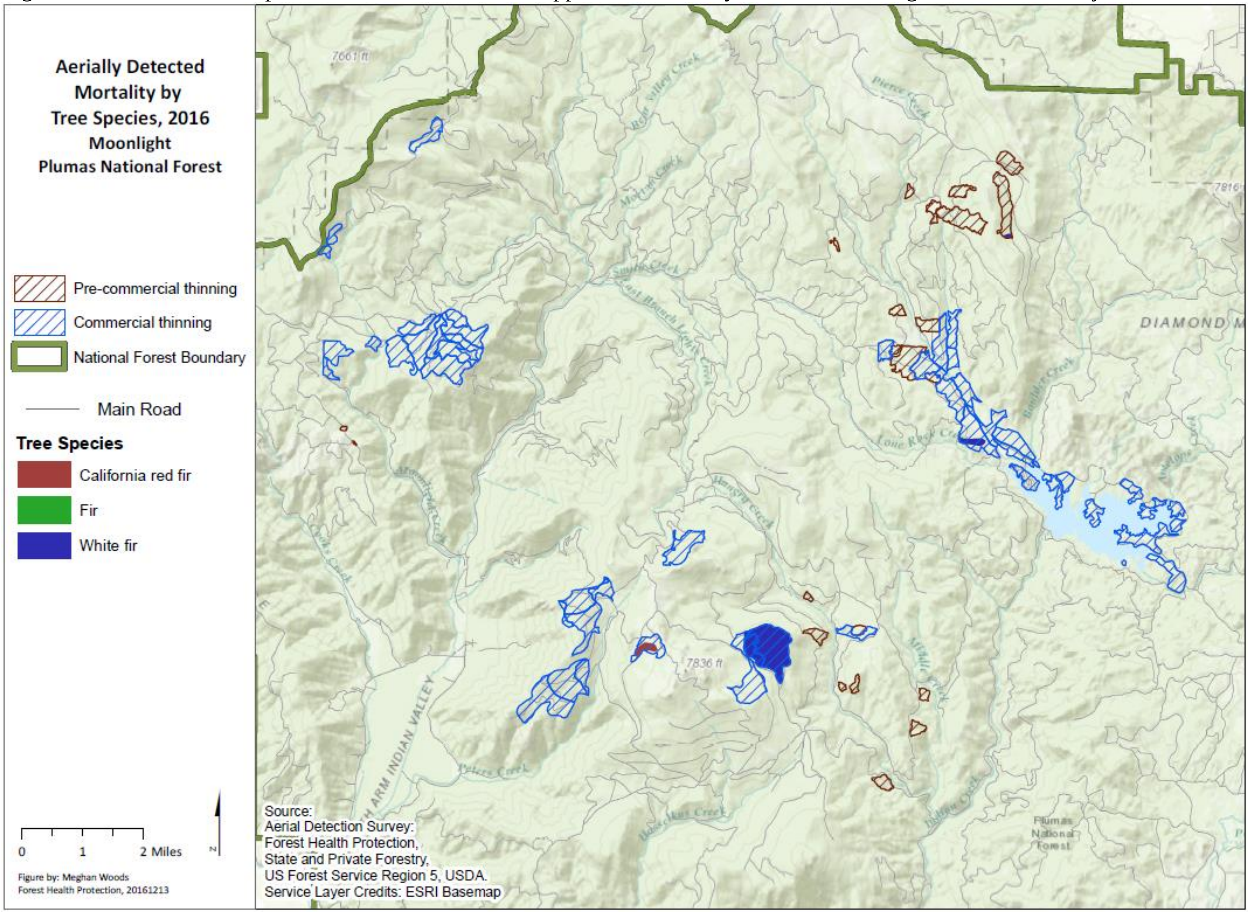
White pine blister rust (*Cronartium ribicola*) was observed on several young sugar pine causing branch flagging and top-kill.

Red fir dwarf mistletoe (*Arceuthobium abietinum* f. sp. *magnificae*) combined with Cytospora canker (*Cytospora abietis*) is causing branch flagging of red fir in higher elevation mixed conifer stands.

Figure 2. Fruiting body, or conk, of *Heterobasidion occidentale*, the cause of Heterobasidion root disease found in Unit # 424.

Figure 3. Dead and downed trees, mostly from 1987 to 1992 drought.

Figure 4. Commercial and pre-commercial units with mapped tree mortality in 2016 - Moonlight Restoration Project.



Evidence of older bark beetle-caused tree mortality was observed in mixed conifer units (snags and downed logs). Most of this older mortality likely occurred during the 1987 – 1992 drought but additional mortality has been documented within these same units by Region 5 Aerial detection surveys since 2007 (Figures 3, 6 and 7 and Table 1).The Forest Health Protection evaluation of the Lone Rock project in 2014 found slightly elevated levels of ponderosa, Jeffrey and lodgepole pine mortality around Antelope Lake. This mortality was the result of successful bark beetle attacks on trees growing in overstocked stands.

Figure 5. Open stand of codominant trees that survived the Moonlight Fire, Unit #421. Prior fuels reduction treatments increased tree survival in this stand.

Stand conditions and mortality related to recent and future climate trends

Most of the commercial and pre-commercial units within the Moonlight Restoration project appear to be at or above "normal" stocking levels and have exhibited an elevated level of tree mortality caused by bark beetles during and after periods of drought (Figures 6 and 7 and Table 1). This mortality combined with high stand density has resulted in heavy fuel loading in many areas and a corresponding increase in potential fire behavior. An exception to this would be any commercial units that are similar to unit #421. This unit had a prior fuels treatment before the Moonlight fire, burned at light to moderate vegetation severity and observed stocking appears suitable for the site (Figure 5).

Current tree mortality attributable to insects and/or pathogens is slightly elevated within the commercial and pre-commercial units. However, aerial detection surveys have identified a sharp increase in mortality during the past year (Table 1). Elevated levels of tree mortality in this area,

Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (average of CA Divisions 2 and 3[1]) by water year (Oct-Sept) within commercial and pre-commercial thinning units - Moonlight Restoration Project.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[2]
2016	365	3.1	1,114	-1.28
2015	65	1.5	95	-3.34
2014	2	2.5	5	-3.56
2013	38	1.6	60	-2.16
2012	340	1.6	531	-0.59
2011	797	3.1	2,472	2.78
2010	602	8.0	4,813	-0.14
2009	922	4.5	4,171	-2.98
2008	0	0	0	-3.16
2007	0	0	0	-3.17

[1] California Divisions 2 and 3 encompass most of northeastern California. The Moonlight Restoration Project is on the border between these two zones.

[2] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

Figure 6. Commercial and pre-commercial units, number of years with mapped tree mortality - Moonlight Restoration Project.

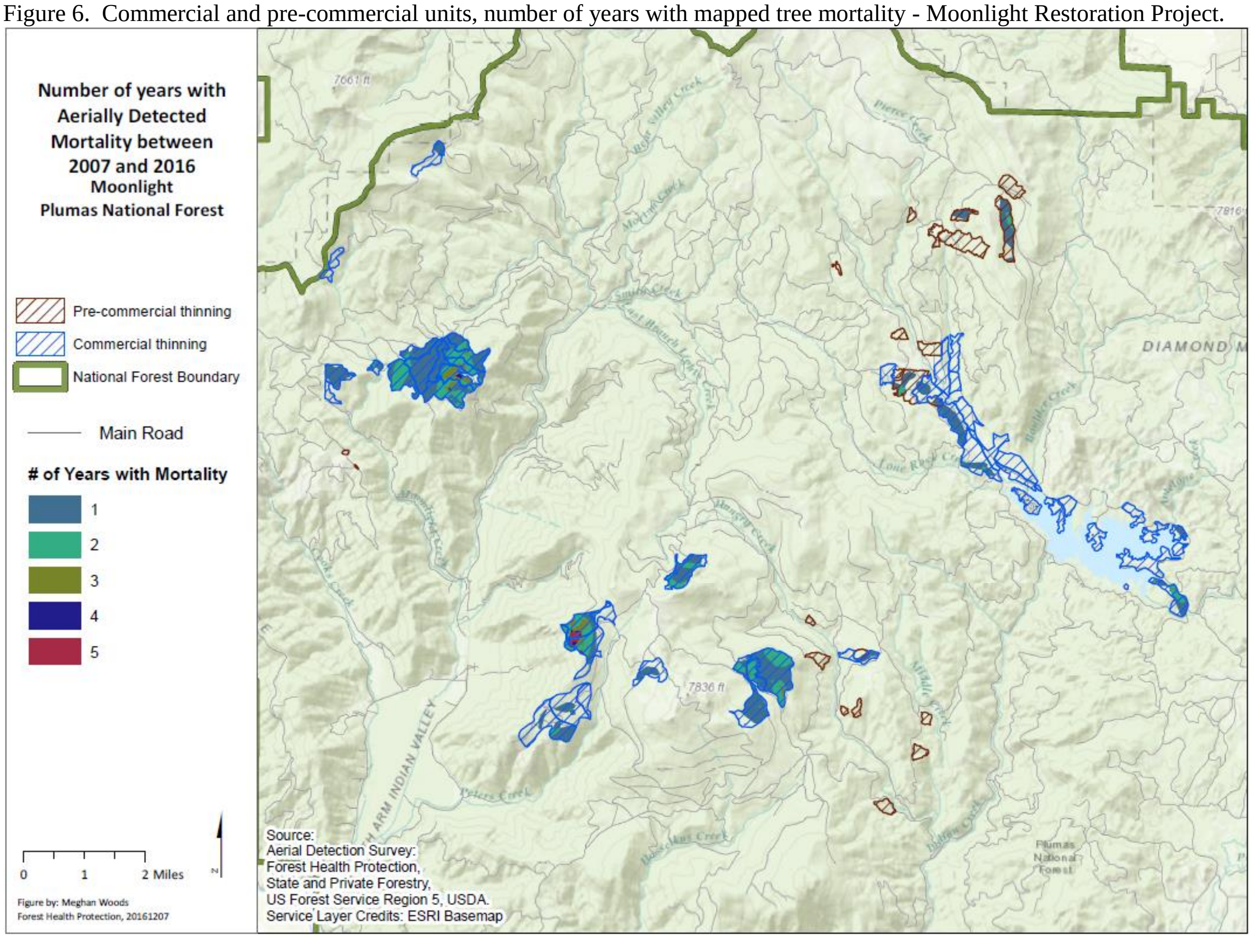
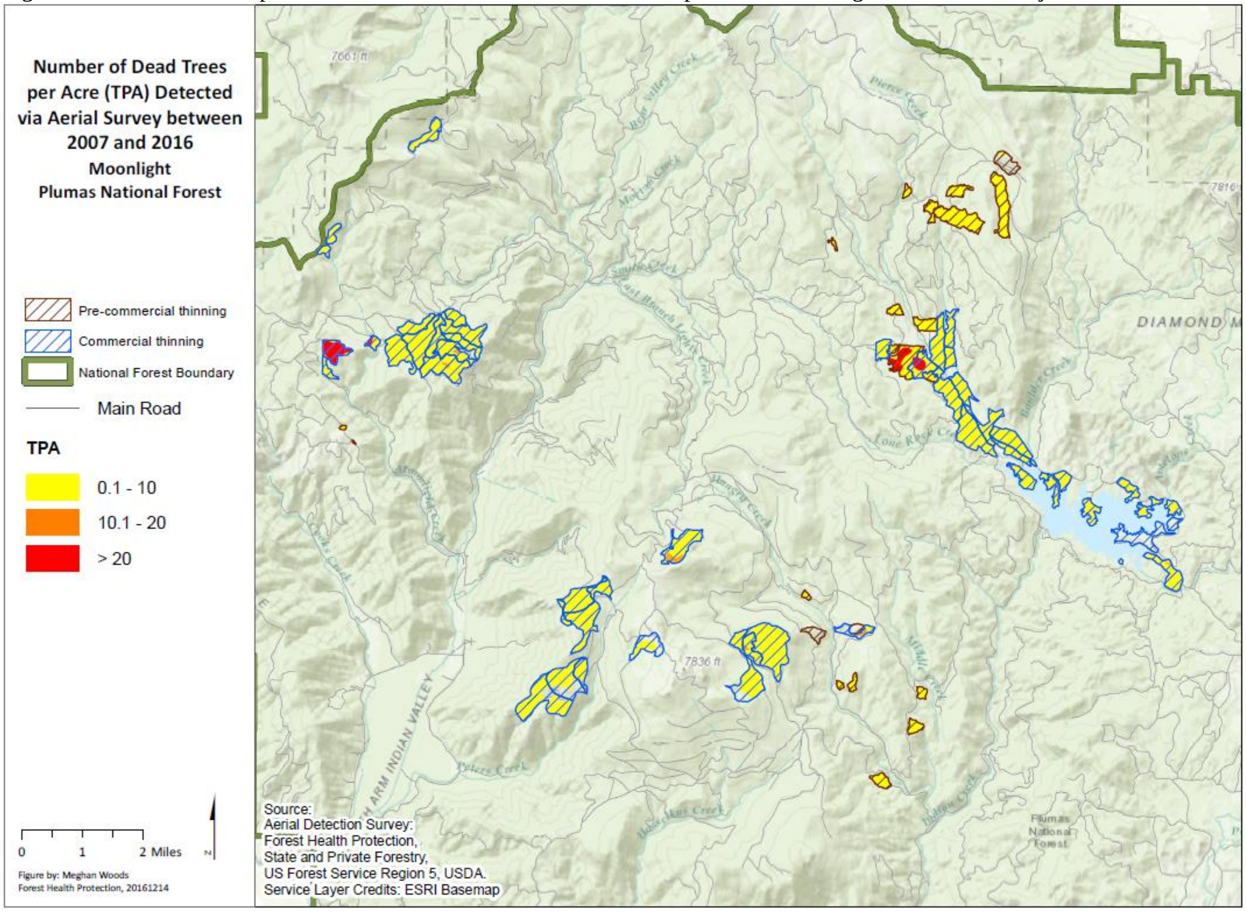


Figure 7. Commercial and pre-commercial units, number of dead trees per acre - Moonlight Restoration Project.



as well as in the rest of the Sierra Nevada range, are strongly associated with periods of below normal precipitation and high stand density. Successive dry years can exacerbate unhealthy stand conditions, such as those that exist within the Moonlight Restoration Project treatment units; resulting in higher levels of bark beetle-caused tree mortality. The Palmer Hydrologic Drought Index is also included in Table 1 to show the relationship between drought and tree mortality.

Figures 6 and 7 also depict many forested areas where no mortality was mapped during the past 10 years. However, many of these stands should be considered highly susceptible to bark beetle-caused tree mortality due to overstocked conditions and could experience unacceptable levels of tree mortality during prolonged and/or severe drought. For example, the current exceptional drought in the south Sierra Nevada range has resulted in high levels of mortality in mixed conifer stands similar to the Moonlight Restoration project stands. Anticipating future drought events and reducing tree density to levels that are more resilient and sustainable should reduce the risk of unacceptable levels of tree mortality within the Moonlight Restoration Project area.

Predicted climate change is likely to impact trees growing in the Moonlight Restoration area over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*. The risk of bark beetle-caused tree mortality will

likely increase for all conifer species under this scenario, especially drought intolerant white fir and overly dense stands of ponderosa and Jeffrey pine. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

General considerations for thinning treatments

Most of the thinning treatments proposed by the District should reduce stand density to a level that significantly lowers the susceptibility to bark beetle caused mortality. In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality.

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines, should benefit by having the stocking around them reduced to lower levels. Areas of eastside pine (ponderosa and Jeffrey) would also benefit from lower stocking levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees, or on more mesic north-facing slopes. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Regional ecosystem restoration goals. Many of these methods are also consistent with past FHP recommendations for thinning in mixed conifer stands and their use is supported for the Moonlight Restoration project.

The diameter limits established for cutting trees (<6" dbh) within wildlife habitat areas may achieve some short-term fuel reduction objectives but will not likely result in sufficient density reduction to lower the susceptibility to bark beetle-caused mortality during droughts. Excessive tree mortality during future droughts could reduce the effectiveness of fuel treatments as dead trees fall to the ground. Excessive numbers of dead trees may also reduce habitat suitability due to a reduction in canopy cover. Thoroughly treating stands adjacent to these wildlife habitat areas to reduce the risk of high severity wildfire and the susceptibility to bark beetle-caused mortality will be vital to maintaining heterogeneity on the landscape and provide current and future wildlife habitat.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14" in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. An exception to this recommendation would be for white fir in eastside pine or mixed conifer stands if there is already a high level of *H. occidentale* (S-type) present. Treating white fir stumps in heavily infected stands is ineffective. It is also not necessary to treat Douglas-fir stumps with a borate compound for the prevention of Heterobasidion root disease. Douglas-fir has a low susceptibility to *H. occidentale* and appears to be healthy where it is growing within and adjacent to suspected root disease centers in white fir.

For the campgrounds within the Antelope Lake Recreation Area, all conifer stumps greater than 3" in diameter must be treated with a registered borate compound (FSM R5 Supplement 2300-92-1 modified by FSH R5 Supplement 3409.11-2010-1) to reduce the probability of infection by

Heterobasidion occidentale and *H. irregulare.* The causal agents of Heterobasidion root disease (formerly referred to as annosus root disease).

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. An exception to this would be thinning suppressed trees within pure sugar pine groups to reduce inter-tree competition. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

Conditions and Recommendations for Specific Units

Unit #426

This unit is a California Spotted Owl habitat maintenance unit. Historic timber harvest has removed a portion of the large tree component (mostly yellow pine and Douglas-fir) and fire exclusion has resulted in the establishment of a dense understory of white fir (Figure 8). Heterobasidion root disease and true fir dwarf mistletoe have seriously impacted white fir health within this stand (Figure 9). These two pathogens have caused tree mortality, crown decline, growth loss and stem deformities for this species. Many of the infected trees are greater than 6” dbh and will remain as a stand component after hand thinning of smaller material, continuing their decline and further infecting any new white fir regeneration that becomes established. Infected white fir will grow slowly with high levels of mortality, greatly limiting the number of individuals that could grow into dominant canopy positions and contribute to future crown closure. This area is also considered to be at medium risk for white fir mortality during drought due to receiving less than 40” of average annual precipitation (Shultz 1994).

Figure 8. Dense stand of small diameter white fir within CASPOW habitat maintenance unit # 426.

Figure 9. Declining white fir due to root disease and dwarf mistletoe infection within CASPOW habitat maintenance unit # 426.

Many >6” dbh white fir are also growing under the crowns of the remaining large diameter trees and could function as ladder fuels during a wildfire.

The District should consider raising the upper diameter limit restriction for white fir in this stand to remove more root diseased and dwarf mistletoe infected trees and trees growing under and into the crowns of larger diameter trees. This would serve to protect large diameter trees

from fire and create openings for the regeneration of other species such as ponderosa pine, sugar pine and Douglas-fir. When hand thinning smaller diameter trees, preference should be given to retaining healthy pine species, Douglas-fir and incense cedar over white fir.

Unit #426

This unit is a proposed commercial thin unit that burned during the Moonlight fire causing low levels of tree mortality, mostly of smaller diameter trees. This unit also had a fuels reduction treatment prior to the Moonlight fire which is likely responsible the high survivorship of trees within the stand. Other than a few slightly dense cohorts of intermediate/codominant trees, most of the stand consists of dominant and codominant ponderosa pine, sugar pine, Douglas-fir and incense cedar at relatively wide spacing. The need for commercial thinning in these types of units should be confirmed. In addition to or instead of commercial thinning, there may be a need to reduce fuels as a result of dead and downed fire-killed trees and abundant brush growth since 2007 (Figure 5).

Unit #424

Unit #424 is a proposed commercial thin unit that consists of a dense mixed conifer stand with a red fir component. White fir is the dominant tree species but there are scattered ponderosa pine and sugar pine within the stand. This unit had the highest number of recently dead white fir, mostly associated with Heterobasidion root disease (Figure 10). Red fir mortality was also evident from a combination of root disease, dwarf mistletoe and Cytospora canker. In addition to the recent mortality, there is substantial amount of dead wood most likely the result of tree mortality during the 1987 to 1992 drought.

Figure 10. Group of dead and dying white and red fir infected with Heterobasidion root disease in Unit # 424.

The District should consider a variable thinning strategy to decrease the number of diseased white and red fir and enhance regeneration of pine species. Identifying root disease pockets and removing all susceptible hosts would provide openings to plant pine species, especially rust resistant sugar pine. Openings could also be created to reduce the number of dwarf mistletoe infested trees, allowing for the establishment of understory vegetation in the short-term and natural regeneration of true fir over the long-term. This would enhance heterogeneity within the stand and allow for regeneration of dwarf mistletoe free white and red fir. These openings can vary in size but should be large enough to provide a significant buffer from infected overstory trees that can spread dwarf mistletoe seed horizontally up to 60 feet. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree.

Unit #400

This unit is a proposed commercial thin in a ponderosa pine plantation. This pine plantation consist of sawlog sized trees and pre-commercial sized trees (<10” dbh). Some of the pines have not grown especially well in this higher elevation and wetter location, with many sustaining

snow injuries that have caused mild growth deformity. Natural regeneration of white fir has occurred among the planted pines and appears healthy. A few sugar pine saplings were also observed.

This plantation should be thinned to spacing to maximize growth of planted pines. When thinning, all non-pine species should be retained to increase species diversity.

Unit #456

Unit #456 is a relatively young mixed conifer stand that may have established after wildfire or past timber harvest. It is located adjacent to Unit #400 (ponderosa pine plantation) and appears to be roughly the same age. There are also smaller planted pockets of pine within the mixed conifer and the occasional large diameter tree or large tree cohort. White fir makes up the largest portion of the species composition.

This area should also be thinned to spacing to maximize growth of all species with an emphasis on removing white fir in favor of other conifer species.

Units #437, 454, 440 and 455

These units were evaluated in 2014 as part of the Lone Rock Forest Health project. The following is the description and recommendation from the resulting FHP evaluation (FHP Report NE14-04).

In the Lone Rock and Boulder campgrounds (Unit #437) the average basal area (BA) is 273 sq. ft./acre and the stand density index (SDI) is 459. In the day-use area (Units #440, 454 and 455), the average BA is 231 sq. ft./acre and the SDI is 452. These SDI values are well above the bark beetle limiting SDI of 365 for ponderosa pine. SDI 365 is considered the upper management zone above which bark beetle outbreaks are likely to occur (Oliver 1995). Egan (2011 and 2012) reported that Jeffrey pine resilience thresholds were consistent with experimental studies within ponderosa pine systems based on a detailed study of a Jeffrey pine beetle outbreak in the Lake Tahoe area. This Jeffrey pine beetle outbreak which occurred from 1991 to 1996 followed the severe drought period of 1987-1992. Stands with the highest mortality (>150 trees/acre) were above SDI 350. Oliver suggests that ponderosa pine stands be maintained below SDI 230 to minimize the level of western pine beetle-caused mortality. Egan suggests Jeffrey pine stands be maintained below SDI 210 or 125 sq. ft. /acre to minimize Jeffrey pine beetle-caused mortality. Stands that were between SDI 111 and 210 experienced much lower mortality during the outbreak (14 trees/acre). No mortality was reported for stands that were at or below SDI 110.

Unit #311

This unit is a young Ponderosa and Jeffrey pine plantation that is representative of most pre-commercial units. It generally consists of trees <10" dbh that are currently overstocked or will be within a few years. Thinning to increase growth and vigor will accelerate stand structures that are more resilient to fire and keeping stocking at lower levels will decrease the chances of bark beetle-caused mortality.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning, it may result in unacceptable levels of tree mortality; depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa, Jeffrey and especially sugar pines are susceptible to lethal basal cambium damage during prescribed burns from the heat that develops in the deep duff and litter that accumulates at their bases. These duff mounds typically burn at a slow rate with lethal temperatures, causing severe injury to the cambium which girdles the trees. To protect individual high-value large diameter pine from lethal cambium damage, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

Potential for funding thought the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning and removing green material from overstocked areas within the Moonlight Restoration project area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

Daniel R. Cluck
Forest Entomologist
NE CA Shared Services Area

cc: Beth Waterston, Forester, VMS Enterprise Unit
Maurice Huynh, District Silviculturist, Mt. Hough RD
Ryan Tompkins, Forest Silviculturist, Plumas SO
Forest Health Protection, Regional Office

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Insect and Disease Information

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4” in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4” in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host

species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development

These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree completion, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae,* attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature

lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

Jeffrey pine beetle

The Jeffrey pine beetle is the principle bark beetle found attacking Jeffrey pine, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill groups of trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

Evidence of Attack

Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish

brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree. If examined carefully, pitch tubes can be detected on infested green trees prior to crown fade. Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines extend across the grain and end in open, oval-shaped pupal cells.

Life Stages and Development

The Jeffrey pine beetle is one of the larger pine bark beetles in California. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximately five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October. Similar to other *Dendroctonus* species, Jeffrey pine beetles use pheromones that attract other beetles to a tree, causing a mass attack that tends to overcome the tree's natural resistance. Blue stain fungi are associated with Jeffrey pine beetle attacks and aid in overcoming the tree’s defenses.

Conditions Affecting Outbreaks

Normally the Jeffrey pine beetle is kept in check by its natural enemies, climatic factors and the resistance of its host. Similar to other *Dendroctonus* species, the availability of suitable host material is a key factor influencing outbreaks. Healthy trees ordinarily produce abundant amounts of resin, which pitches out attacking beetles. When deprived of moisture, or stressed by other factors such as disease or fire injury, trees cannot produce sufficient resin flow and become susceptible to successful beetle attacks.

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such

as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

Cytospora Canker of True Firs

Cytospora abietis is a damaging, canker-inducing fungus that commonly occurs on true firs throughout their natural range in California, central and eastern Oregon, and frequently on firs and Douglas-fir elsewhere in the western United States. A weak parasite, it attacks only trees that have been debilitated by other disease-causing agents, drought, fire, insects, and human activities.

One of the important factors that predispose firs to infection by *C. abietis* is dwarf mistletoe. Practically all fir stands in California and Oregon infested with dwarf mistletoe are infested with this fungus. *C. abietis* more commonly infects branches invaded by dwarf mistletoe and in some stands nearly a fourth of all branches bearing mistletoe are infected. Thus, in mistletoe-infected fir stands, considerable branch killing occurs each year as a result of this canker organism and occasionally trees are killed. Because this fungus sometimes reaches damaging proportions, *C. abietis* can constitute a threat to the management of true firs.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.